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The heat supply object thermal regime under conditions of gas infrared emitter and air exchange system joint operation

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Abstract. The paper presents the results of experimental studies on the formation of thermal comfort conditions in large premises with the joint operation of gas infrared emitters and air exchange ventilation system. The values of temperatures and heat fluxes on the clothing surface under natural and mixed convection conditions were obtained. It has been established that the air exchange system operation in the premises reduces the temperature drop of the person clothes surface, respectively, a more favorable temperature condition is achieved in the working area.

1. Introduction

Improving the building energy efficiency and creating thermal comfort are becoming more and more urgent tasks in the modern world [1-4]. Increasingly stringent requirements in the field of building energy efficiency [3] are forcing industrial enterprises to look for the ways to improve energy efficiency during their operation [4]. In recent years, gas infrared emitters (GIE) [5-7], co-operating with supply and exhaust ventilation [8], have been increasingly used as one of the effective systems for ensuring thermal conditions in buildings and structures. The particular importance is the task of increasing the person thermal comfort in the local working area [9, 10]. There are no results of an objective analysis of the thermal regimes of such objects necessary for predicting the main characteristics of thermal comfort for the widespread introduction of GIE. The purpose of the study is to establish the influence of gas infrared emitter and an air exchange system joint operation on the characteristic temperatures of a typical heat supply object.

2. Experimental technique

Experimental studies were carried out in a closed premise with overall dimensions of 10.2x4.9x4.4 m (Fig. 1).

The gas infrared emitter was located 2.975 m above the floor. The high-intensity GIE type with the power of 5 kW was used in the study. The premise floor was made of concrete coated with ceramic tiles. Directly under the GIE is a mock-up of the research object covered with a fabric (Fig. 1). The initial air temperature varied from 18 to 20°C. At the same time, the outside air temperature was from 0 to -10°C. The laboratory was equipped with supply and exhaust ventilation system to remove the gas combustion products released during the operation of the high-intensity GIE type. The capacity of the supply and exhaust ventilation system was 420 m^3/h. The air ducts were located at a distance of 0.3 m from the ceiling. The supply air temperature was 10°C as a result of the electric air heater operation. Temperature measurements were carried out with chromel-alumel thermocouples (the coordinates of their position are given in Table 1) with a junction diameter of 80 μm (the systematic measurement

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error according to the passport is not more than 0.4°C). The thermocouple junctions were placed in such a way as to avoid their direct radiation heating. The round heat flux sensors were used to estimate the heat flux to the study object. The error of these sensors did not exceed 1% under experimental conditions. The total heat flux sensors were also located on the surface of the fabric. The signals from the sensors were transmitted with an interval of no more than 1 s and were processed by the measuring complex, which was located outside the investigated premise.

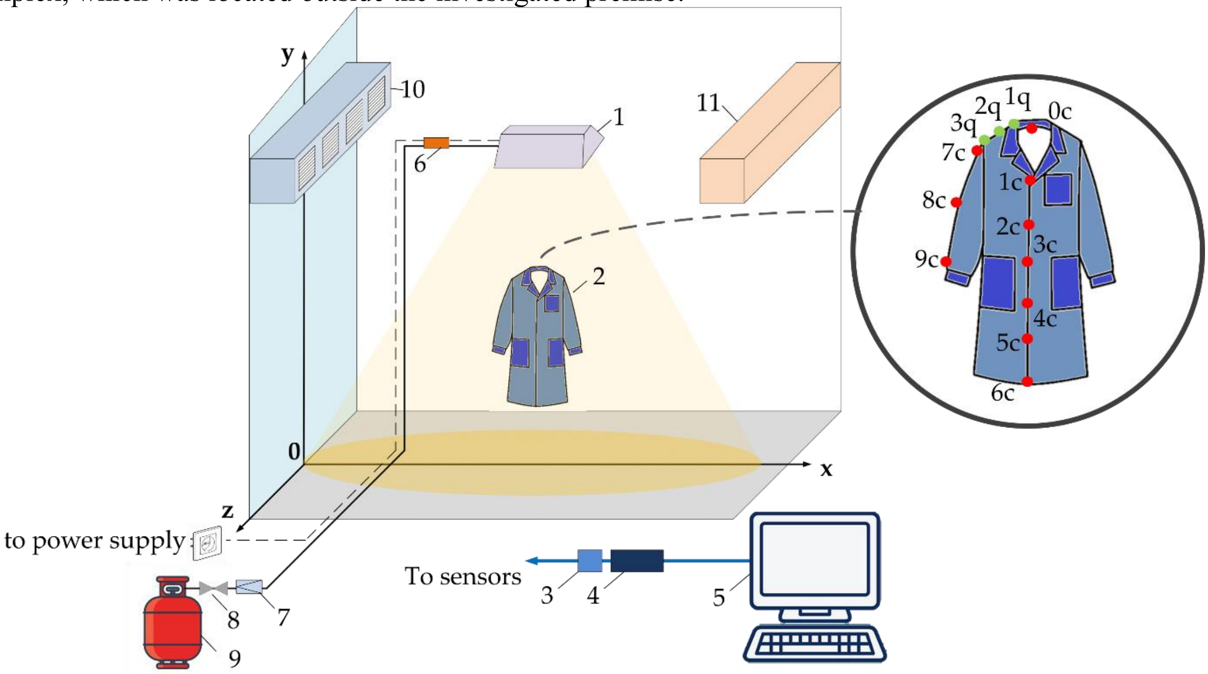

Figure 1. The scheme of experimental setup: 1 – GIE; 2 – The study object; 3 – Signal converter; 4 – Data collection system; 5 – PC; 6 – GIE control unit; 7 – Gas control valve; 8 – Gas cylinder valve; 9 – Gas cylinder; 10 – Inlet ventilation; 11 – Outlet ventilation; 0c – 9c – The study object thermocouples; 1q – 3q – Heat flux sensors.

Table 1. The heat flux sensors and thermocouples location and the angles between the direction of the radiant heat flux and the normal to the surface (αf)

Heat flux sensors										
№	1q		2q		3q					
x, m	1.6		1.45		1.30					
y, m	1.6		1.55		1.50					
z, m	0.0		0.0		0.0					
αf, deg	20		20		20					
The study object thermocouples										
№	0c	1c	2c	3c	4c	5c	6c	7c	8c	9c
x, m	1,6	1.6	1.6	1.6	1.6	1.6	1.6	1.3	1.2	1.1
y, m	1,6	1.4	1.2	1.0	0.8	0.6	0.4	1.6	1.3	1.0
z, m	0,0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
αf, deg	10	90	90	90	90	90	90	10	10	10

3. Experimental results

Figures 2-5 show the main experimental results in natural and mixed convection conditions. Figure 2 reflects the dependence of study object surface (fabric) temperatures on the height vs time. At the initial moment (before the GIE operation), the premise air temperature was 18°C and monotonously increased to 22.5 ÷ 24.5°C for most thermocouples by the 90th minute of the experiment. The thermocouple located at the point with coordinates (1.6; 1.6; 0) recorded a higher temperature value for both natural and forced convection conditions because it was closest to the emitter and αf was 10 degrees. After 80 minutes of GIE operation, the temperatures almost did not change (a stationary regime set in).

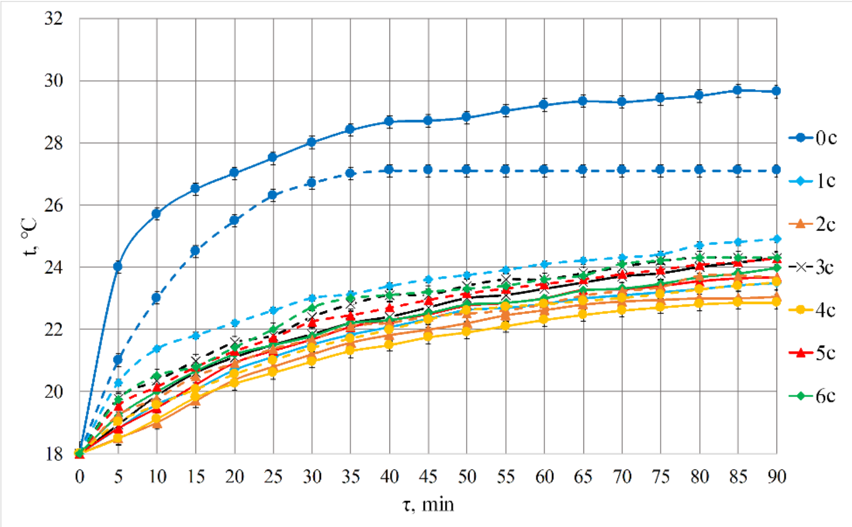

Figure 2. The study object temperature change by height from the floor under GIE in natural (solid line) and mixed (dashed line) convection conditions.

It should be noted that the temperature values on an inclined surface with αf = 10° (Fig. 1, thermocouples 7c, 8c, 9c) continued to increase (Fig. 3) until the end of the experiment (90 minutes). The reading of these thermocouples was higher and reached 27°C (thermocouple 7c).

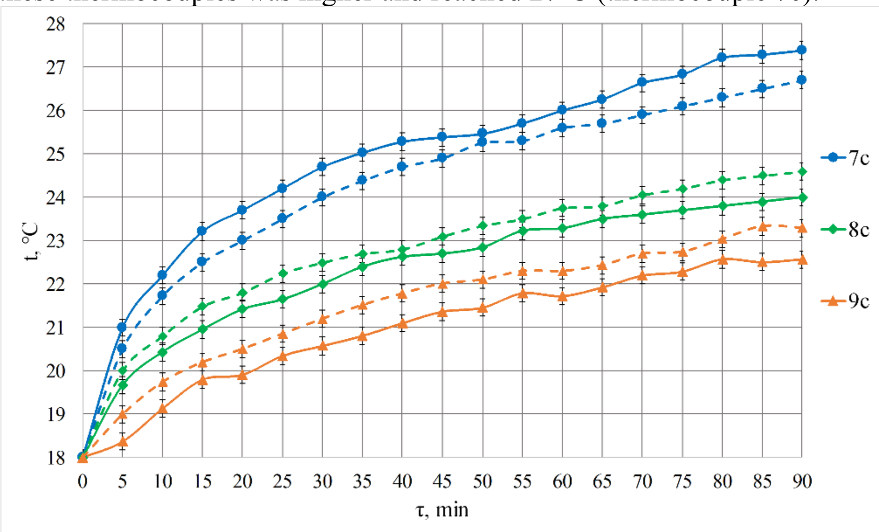

Figure 3. The study object temperature change in 7c - 9c thermocouples under GIE in natural (solid line) and mixed (dashed line) convection conditions.

Figure 4 shows the total heat fluxes to the upper surface of the study object (Fig. 1). Heat fluxes sharply increase after the start of gas infrared emitter operation and after 5-6 minutes it takes on values almost unchanged until the end of the experiment. In the case of the supply and exhaust ventilation system operation (mixed convection condition), the *q* value is higher than in the natural convection case. This result is due to the intensification of heat transfer processes (radiant and convective components) between the study object surface and the GIE.

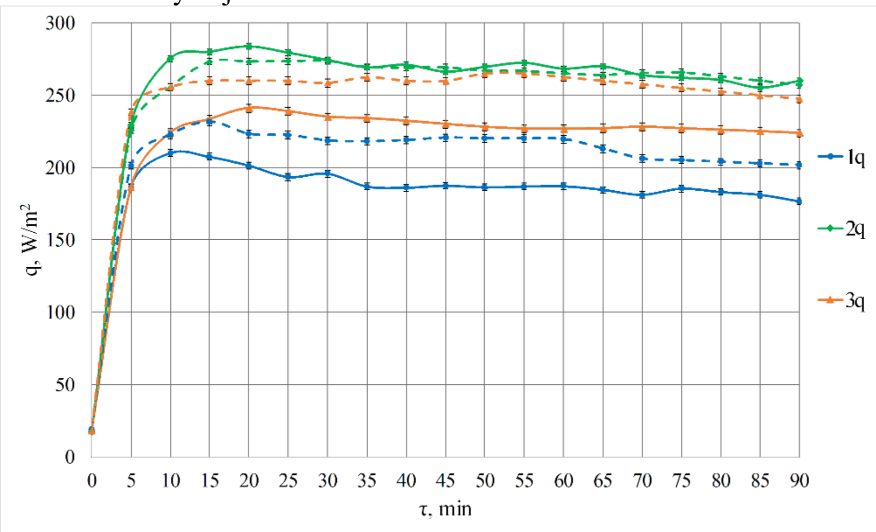

Figure 4. The change in the heat flux to study object under GIE in natural (solid line) and mixed (dashed line) convection conditions.

Figure 5 shows the surface temperature distribution on the study object (fabric) along with the height. The largest temperature difference falls in the height range from 1.4 to 1.6 m and is about 6°C (from 15 to 90 minutes) for natural convection conditions and 2°C for mixed convection conditions. At a height of 0.4 to 1.4 m, the temperature deviation is no more than 1 degree for both natural and forced convection. In the mixed convection conditions, the fabric surface temperature at a height of 1.6 m is 2 degrees lower than in the natural convection condition, and at y = 1.4 m the values are 1.5 °C higher. The fabric surface temperature is lower with decreasing altitude and less dependent on the convection condition. This is most likely due to the fact that the main flow of cold air relative to the main volume, coming from the air exchange system, pushes the heated air away from the GIE into the area corresponding to y = 1.2 ÷ 1.4 m and moves in the area corresponding to y coordinate = 1.6 m, intensifying convective heat transfer.

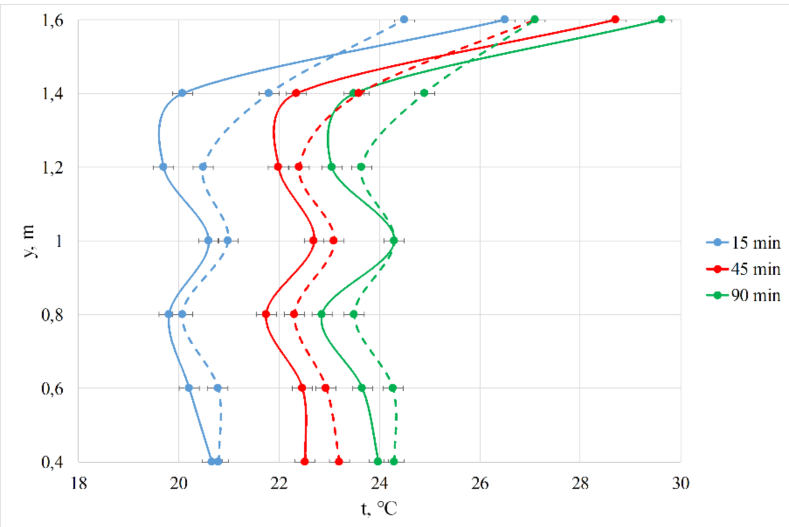

Figure 5. The study object surface temperature change along the height under GIE at different times in natural (solid line) and mixed (dashed line) convection conditions.

Conclusion

It has been established that mixed convection with a relatively cool air inlet has a zonal effect on the thermal regime of the heat supply object. In the upper part of the object under study, the fabric surface temperature is 3°C lower as compared to that under natural convection condition. In the rest of the clothing, the air exchange system operation effect is insignificant. It can be concluded that the supply and exhaust ventilation operation improves the temperature comfort conditions because the temperature drop of the worker cloth surface decreases by height.

Acknowledgments

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